

COMMERCIAL REMOTE SENSING TECHNOLOGIES APPLICATION TO TRANSPORTATION

A PARTNERSHIP FOR ADVANCING TRANSPORTATION PRACTICE



A Collaborative Partnership Research Program



U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



REMOTE SENSING TECHNOLOGIES APPLICATION TO TRANSPORTATION

INTEGRATED PROGRAM MANAGEMENT

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USDOT

Bureau of Transportation Statistics
Federal Aviation Administration
Federal Highway Administration
Federal Motor Carrier Safety Administration
Federal Railroad Administration
Federal Transit Administration
Maritime Administration
National Highway Traffic Safety Administration
Research and Special Programs Administration

NASA

Ames Research Center
Dryden Flight Research Center
Glenn Research Center at Lewis Field
Jet Propulsion Laboratory
Johnson Space Center
Kennedy Space Center
Langley Research Center
George C. Marshall Space Flight Center
Goddard Space Flight Center
John C. Stennis Space Center

SETTING THE STAGE

The Transportation Equity Act for the 21st Century, 1998 (TEA 21 Section 5113) provides for developing and implementing a program “...to validate commercial remote sensing products and spatial information technologies for application to national transportation infrastructure development and construction” in cooperation with the National Aeronautics and Space Administration (NASA), university consortia, and others.

The U.S. Department of Transportation (DOT) has implemented a research program in partnership with leading academic institutions, service providers, and industry for remote sensing in transportation. The program is designed to serve long-term research for education and workforce development and near-term technology applications to transportation practice. The program combines NASA research expertise in remote sensing with DOT expertise in technology assessment and application to transportation practice. DOT and NASA have entered into a Memorandum of Understanding (MOU) to work together to implement a fully integrated and coordinated research program on applying remote sensing to transportation. (See <http://scitech.dot.gov>.)

The program seeks innovative applications of commercial remote sensing and geospatial information technologies to solve priority transportation requirements. The program is carried out in two major integrated parts:

- (1) University consortia programs to advance remote sensing technology base. Each consortium will serve as a one-stop center for providing technical assistance to state and local agencies on remote sensing applications in the area of consortium expertise; and*
- (2) Short-term technology application projects carried out by service providers and industries to demonstrate on-site application of remote sensing technology to transportation practice.*

The program is administered by the Department of Transportation’s Research and Special Programs Administration (RSPA) in coordination with nine additional DOT administrations. The program is managed by the RSPA Office of Innovation, Research and Education. The office is responsible for integrated and cross-cutting research and special programs for achieving the goal of ensuring transportation safety, enhancing mobility, reducing environmental impact, promoting economic growth and ensuring national security. The office also manages thirty-three University Transportation Research Centers performing interdisciplinary and multimodal transportation research.

The mission of NASA’s Earth Science Enterprise (ESE) (Office of Earth Science) is to study our planet from the vantage point of space and apply NASA’s unique scientific and technical capabilities to promoting issues of national and global concern. The Applications Division of ESE focuses on extending NASA science and technology results beyond the traditional Earth Science research and turn Earth Science results and capabilities into tools for solving practical problems at national and regional levels. A program coordination and integration office has been established at NASA/ESE jointly with DOT.

The products from the program will effectively address meeting the following important transportation requirements:

- Traffic surveillance, monitoring and management*
- Environmental assessment, integration and streamlining*
- Transportation infrastructure management*
- Hazards, safety, and disaster assessment*

All projects and consortia programs have cost-sharing commitments from participants in cooperation with product users.

TRAFFIC SURVEILLANCE, MONITORING AND MANAGEMENT

Transportation is the flow of people and goods between geographically separated locations. Therefore, efficient management of the flow is critical to efficient transportation. Public agencies responsible for providing and maintaining the transportation infrastructure expend significant resources to estimate traffic flow patterns under prevailing conditions and forecast patterns that would result from operational or policy alternatives. Monitoring of vehicle traffic volumes, classifications, speeds, and truck weights are obtained across the state highway network and processed to produce data used in planning and forecasting, pavement design, traffic studies, level of service determination, gas tax redistribution, and accident analysis. However, states find it expensive and difficult to achieve the desired regional coverage. Better quality and more flow data would lead to improved estimates in forecasting traffic flows. Airborne and satellite platforms offer the potential to obtain wide spatial coverage not offered by ground-based sensors and provide a potential for monitoring regional spatial transportation flow conditions.



Traffic monitoring of trucks and automobiles on a segment of interstate highway



Hypothetical image to illustrate traffic management and control



Air photograph of intermodal shipments including river, road and railroad connections

The National Consortium on Remote Sensing in Transportation-Flows (NCRST-F), led by The Ohio State University, focuses research on improving the efficiency of transportation teams at the national, state, regional and local levels by integrating remotely sensed traffic flow data obtained from airborne or satellite platforms and matching them with traditional data collected from ground-based sensors. The consortium focuses research on the following areas:

- Developing methods that provide better and cheaper flow-related data and information as well as facilitating the implementation of these methods
- Increasing awareness of the benefits of remote sensing in transportation among practicing professionals and developing an educated transportation workforce.

Consortium researchers and educators will consider the collection and use of remotely sensed data from satellite and airborne platforms as a system that includes data collected from ground-based sensors in the pursuit of three general flow-related applications: highway traffic monitoring, highway traffic management, and freight and intermodal transportation analysis.

The Ohio State State University Consortium, NCRST-F

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ASSOCIATED TECHNOLOGY APPLICATION PROJECTS BY SERVICE PROVIDERS

Technology Service Corporation in Trumbull, Connecticut will stage a demonstration on the application of remote sensing technology to highway traffic management. The demonstration will include the identification of road networks and the development of optimal route planning tools for new and upgraded road construction. The output will enable transportation planners to use a standard GIS environment to carry out their mission. TSC will work with the Maine Department of Transportation in accomplishing project objectives.

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The GeoGraphics Laboratory at Bridgewater State College and the Transportation Center at the University of Massachusetts are developing applications of remote sensing for the transit industry. They will focus on two application products: (1) a transportation demand management (TDM) assessment tool; and (2) a regional transit infrastructure assessment tool. The former will use high-resolution remote sensing imagery at transit TDM facilities to assess the effectiveness of the TDM investment. Remotely piloted aircraft will be used to produce timely and inexpensive imagery at two-inch resolution that can be integrated into digital orthophotos covering large areas. In the regional transit infrastructure assessment tool, historical satellite imagery will monitor changes in land uses that can be associated with regional transit capital projects. These changes will be related to changes in land value from geographic information system (GIS) databases of parcels using assessor's databases. Through this method, the changes in real estate value from public investment in transit capital projects can be measured.

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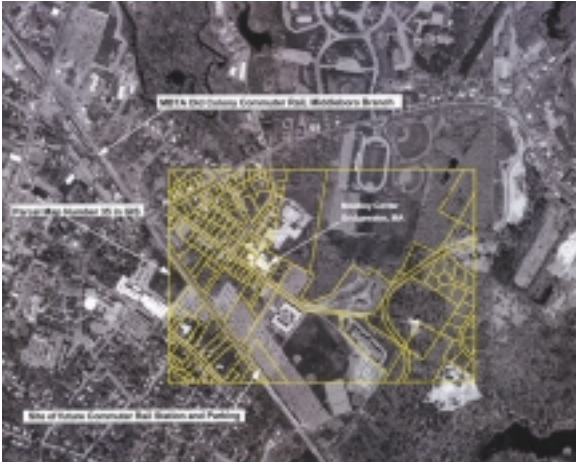
Veridian ERIM International, Inc. in Ann Arbor, Michigan has assembled a diverse team, bridging the private and public sectors, to effectively apply leading-edge remote sensing technologies to operational transportation planning requirements. Veridian will work with the Michigan Department of Transportation and the Pima (Arizona) Association of Governments, and will leverage its significant investment in the development of change detection and spectral feature extraction techniques, to produce remotely-sensed information products and software tools supporting professional transportation planning practices.

The objectives of this project include:

- Development and application of methodologies demonstrating the use of Remote Sensing Imagery (RSI) and GIS technologies for identifying, characterizing and mapping selected transportation features;
- Development of criteria and metrics for evaluation of benefits over traditional methods, including improvements in information quality, from satellite remote sensing-derived database layers;
- Wide-spread distribution of project-developed data, methods, tools and educational materials supporting information and training needs of local, regional and state transportation planners.



Ikonos Imagery and other databases will be employed via dynamic programming algorithms to minimize road construction costs.



A 1-Meter resolution digital orthophoto of the Bridgewater, Massachusetts business district and the campus of Bridgewater State College from 1997. The diagonal linear feature from top left to bottom right is the Middleboro Branch of the Old Colony Railroad. The digital orthophoto is overlain with a GIS database created from a scanned image of a parcel map.

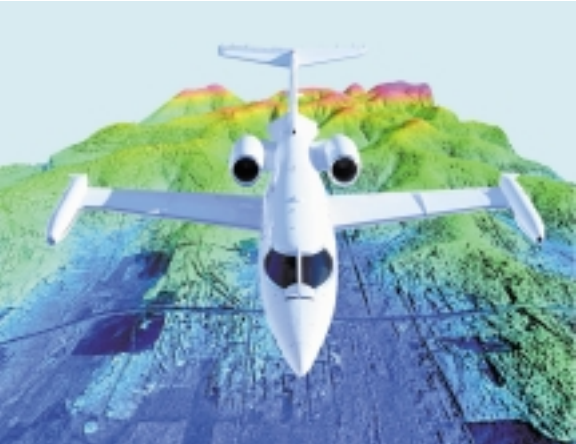


Veridian's Change Vector Analysis (CVA) technique effectively identified and categorized land cover changes in this four-date Landsat image set.

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ENVIRONMENTAL ASSESSMENT, INTEGRATION AND STREAMLINING



Creating Digital Elevation Models with airborne remote sensing tools



False color, multispectral image of new road construction in agricultural landscape



High-resolution aerial imagery for planning new transportation systems in urban landscapes. Image acquired with Positive Systems ADAR 5500 imaging system.

The growth of transportation networks associated with urban growth and sprawl generates a host of environmental impacts ranging from deforestation, impacts on local and regional hydrology, and accentuation or enhancement of such land-atmosphere factors as the urban heat island phenomenon. Remote sensing allows for the synoptic observation and analyses of urban growth. The advent of satellite-based imaging systems that provide spatial resolutions up to 1m facilitates analysis of environmental impacts of urban growth and transportation improvement/development at landscape scales. Moreover, anticipated hyperspectral sensors will provide increased spectral resolution that can be used, potentially, to further the analyses of the state of environmental conditions, and how urban sprawl and associated transportation development impair these conditions.

The National Consortium on Remote Sensing-Environment (NCRST-E) is a consortium of academic, government, not-for-profit, and commercial partners with common goals of:

- Developing innovative remote sensing technology solutions for use in transportation assessment and planning; in particular, the capabilities of new high resolution, multispectral instruments
- Developing the tools necessary to extract information content from remote observations in an efficient manner
- Streamlining and standardizing data processing for information necessary to meet NEPA environmental assessment requirements
- Increasing the awareness and understanding of remote sensing technology through workshops and educational materials.

The consortium will explore applications of remote sensing imagery with increased spatial, radiometric, and temporal resolution for analysis of transportation impact on the environment. The consortium's research will focus on how remote sensing imagery can be used to plan new transportation systems that will minimize their impact on the environment, but still be financially viable; and in developing methodologies for assessing the environmental impacts of existing systems.

Remote sensing-based methodologies need to be developed and verified to demonstrate the viability of their use in environmental assessments of transportation systems. As national transportation demands expand, the encroachment of infrastructure on ecosystems potentially generates adverse impacts on the surrounding environment. Building roads, pipelines, etc. results in a discernible alteration of the local landscape. To effectively monitor the environment around the discrete region of transportation corridors, assessment of adjacent conditions must be performed. Using the results of initial monitoring as a baseline, environmental changes can be identified and the infrastructure relationship to these changes can be studied.

Mississippi State University Consortium, NCRST-E

Mississippi State University	Universities Space Research Association
University of Alabama in Huntsville	NASA Marshall Space Flight Center
University of Mississippi	EarthWatch, Inc.
Auburn University	Intermap Technologies Corp.

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<http://www.rstc.msstate.edu/NCRSTE>

ASSOCIATED TECHNOLOGY APPLICATION PROJECTS BY SERVICE PROVIDERS

ICF Consulting in Fairfax, Virginia will conduct a parallel study on an existing Virginia Department of Transportation (VDOT) road project to use high spatial resolution multispectral satellite data to detect and map environmental features. The study will compare the results of remote sensing analysis with field environmental data and assessments to provide guidance to VDOT on using remote sensing data and image processing techniques for environmental reviews.

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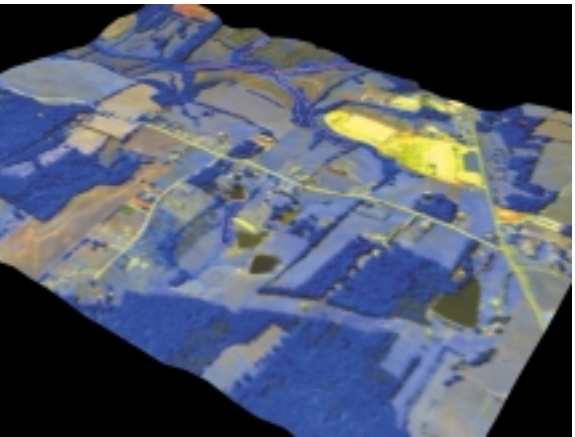


Multispectral false-color composite Ikonos satellite image of the I-64/Route 60 interchange in Newport News, VA

EarthData International in High Point, North Carolina, in partnership with the North Carolina Department of Transportation, will apply airborne remote sensing technologies to streamline the NEPA permitting process, which must balance both progress and growing transportation needs with social and environmental concerns. The technologies employed by EarthData can accelerate the cumbersome decision-making process, by providing detailed information quicker than previously possible to all agencies involved and the public. Using a suite of advanced airborne mapping sensors, EarthData will deliver high-resolution terrain data, wetlands data and ortho-rectified photography for use in corridor selection and alignment approval. EarthData's final product will include a blueprint for integrating these findings into mainstream transportation practice.

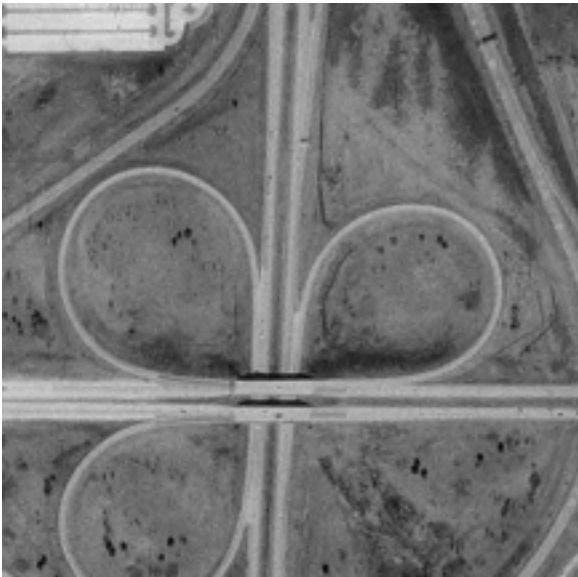
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EarthData used airborne multispectral imagery fused with a LIDAR terrain model to provide detailed information about soils, plant species, standing water, and elevation data for accurate and efficient wetlands identification—a critical step in corridor selection. Here, the wetlands are outlined in magenta.

TRANSPORTATION INFRASTRUCTURE MANAGEMENT



Iowa: Engineering parameters (e.g. radius of curvature from photogrammetry)



California: Centerline extraction and condition monitoring from hyperspectral imagery



Florida: Topographic detail and building footprints

Historically, infrastructure management is conducted on an individual asset-by-asset basis. Management of infrastructure involves systematic maintenance, operation, and renewal of assets such as pavement, bridges, pipelines, rail lines, harbors and airports. Information on the location and condition of these assets is critical to effective management. Many new tools are now available to make the infrastructure management process more efficient, and/or integrative. Remote sensing technology is one of these tools. Advances in the inventory and condition assessment functions of infrastructure management, brought forth by application and development of remote sensing technologies, have the potential for profound impact upon the operations of transportation agencies and transportation users. In order for this impact to be most beneficial, the requirements of each transportation mode (and across modes) for spatial/temporal data must be well understood. Also, the outputs from the inventory and assessment process must be combined with other sources of data in a GIS environment to enhance the assessment of infrastructure performance.

The University of California, Santa Barbara Consortium (NCRST-I) will focus on infrastructure management issues such as inventory and location of assets, condition monitoring, change detection and modeling potential hazards to facilities. The consortium will employ both traditional and emerging technologies to build inventories of infrastructure and to improve the accuracy of map databases. Automated recognition procedures will be developed to detect distinctive patterns such as paved highways, parking lots and airports. Hyperspectral imagery will show subtle differences in material composition, thereby helping to build inventories of bridges and to examine deterioration of pavement. Fusion of LIDAR and digital photography will enable development of “as-built” databases of transportation corridors and associated infrastructure. These can be fed into visualization software to develop “fly-bys,” which are invaluable in planning and disaster response.

In cooperation with leading software vendors, the consortium will extend current transportation data models to facilitate data exchange between organizations; e.g., to allow large-scale construction drawings to be ported to planning-scale applications. Imagery will provide important clues in this process.

University of California, Santa Barbara Consortium, NCRST-I

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ASSOCIATED TECHNOLOGY APPLICATION PROJECTS BY SERVICE PROVIDERS

Tetra Tech ASL in Pasadena, California will study a comprehensive application of remote sensing technology in assessing the final engineering development stages, implementation, operation and growth management of the Alameda Corridor, a \$2.4 billion rail infrastructure project in southern Los Angeles County. When completed in 2002, it will facilitate the flow of goods through the largest port complex in the United States, the combined ports of Los Angeles and Long Beach. The Alameda Corridor provides a unique, real-world test-bed for the validation and verification, demonstration, and transfer of advanced remote sensing technologies to the intermodal transportation sector. The project will develop a *corridor analysis tool*. The tool will use remote sensing imagery and a geographic information system (GIS) to help monitor and plan freight movements, also providing information for facilitating intermodal management of movements and traffic in the Alameda Corridor. Included in the *corridor analysis tool* will be features for urban planning, engineering design and siting, operations monitoring, and environmental and economic impact analyses for the projected growth in the region. Remote sensing and geospatial data will be used to address issues in industrial redevelopment and facilities siting. Geospatial data will be integrated with ground data and traffic models to help plan for optimal operations and managed growth.

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Orbital Imaging Corporation (ORBIMAGE) in Dulles, Virginia, and its partners, Parsons Brinckerhoff and Bentley Systems, will investigate and demonstrate the application of remotely sensed data to planning projects involving five transportation types: roads, railroads, airports, water ports and transmission systems. The project will address all five areas of transportation with the application of road data being the most interactive. The demonstration will incorporate various forms of imagery and GIS data, emphasizing a variety of transportation scenarios. A special project emphasis will be the demonstration of automated techniques for the delivery of remotely sensed digital imagery to the desktops and software environments of transportation professionals. High-resolution imagery containing important regional land features will be used in the demonstration of a number of effective applications for regional transportation planning. The Northern Virginia and Tidewater areas of Virginia will be geographic foci for this project in cooperation with the Virginia Department of Transportation. Much of the aerial and satellite imagery, ground-based imagery, accurate road centerlines, and other GIS data already exists in these areas. By utilizing these existing resources, the Project Team will focus its resources on tailoring the software applications and interacting with transportation planning users through technical exchange meetings and demonstrations.

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Railroad participants in Alameda Corridor project at project kickoff ceremony, December, 1994: Santa Fe (now BNSF), Southern Pacific (now Union Pacific), and Union Pacific

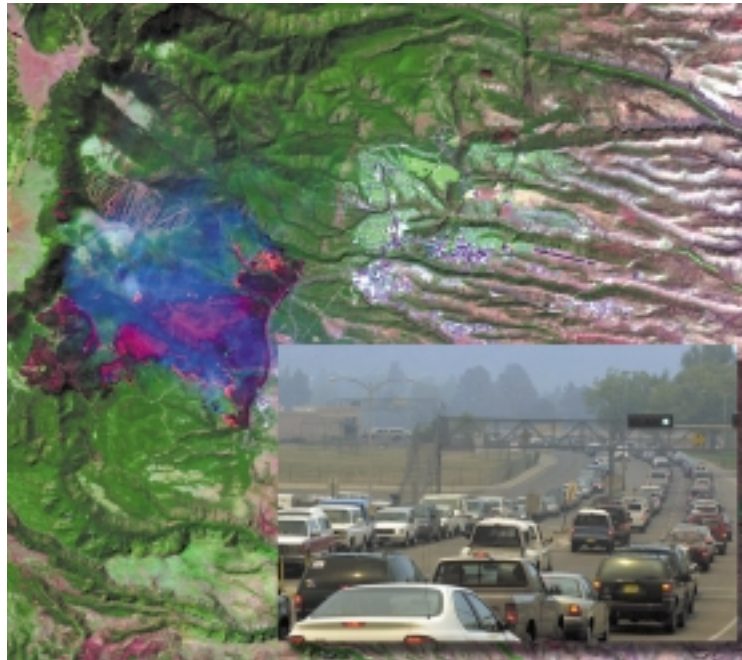


Redondo Junction grade separation and L.A. River railroad bridge at north end of Alameda Corridor



Ten-mile long, 35-foot deep trench portion of Alameda Corridor through urban Los Angeles

HAZARDS, SAFETY AND DISASTER ASSESSMENT



Enhanced Landsat 7 image showing Cerro Grande Fire in Los Alamos, New Mexico. The inset shows the resulting evacuation of Los Alamos. (Photo credit - Ben Margot/AP)



Collapse of Interstate 880 from the 1989 Loma Prieta Earthquake that killed 67 people and caused an estimated 7 billion dollars in property damage, much of that to the transportation system. (NOAA)

University of New Mexico Consortium, NCRST-H

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Needed is the development of transportation applications based on remote sensing and GIS tools that are scalable to new regions for transportation hazards assessment. They must respond to urban and localized hazards, public safety, and disaster assessment needs. The objective of the research is to introduce these tools and applications into broader transportation user communities. The Southwest and Intermountain West face unique problems imposed by vast tracts of sparsely populated terrain dotted with rapidly growing major urban centers and smaller communities. The road and rail systems consist of long segments that are remote from health and safety services, and which require special planning for hazards and disaster relief. Throughout the region, a high percentage of unpaved road surfaces are spectrally similar to surrounding landscapes, making them difficult to identify on imagery. Tribal, rural, and county road nets often suffer poor trafficability because of erosion, flash flood, snow pack, and other weather events. These events often coincide with isolated human tragedies that require a variety of emergency response options.

The University of New Mexico Consortium (NCRST-H) will focus research for identifying and evaluating safety and hazards, as well as assessing impacts of disasters on transportation networks, with accurate and timely information. The consortium focuses its attention on developing spatial analytical tools applicable to issues of safety, hazards, and disaster assessment for transportation lifelines. Existing remote sensing technologies will be assessed for their ability to provide the spatial, spectral, and temporal resolution necessary to effectively meet the needs of transportation planners, emergency services personnel, and disaster management teams. Trafficability and public safety planning associated with floods, fires, earthquakes, evacuation, and E-911 response services will direct the initial research of the consortium. The importance of maintaining transportation lifelines plays a central role in defining the applications to be developed.

Applications to facilitate evacuation planning and implementation are currently under development, as is research into the assessment and consequences of hazards to transportation lifelines and emergency management planning. An application is being developed in cooperation with the New Mexico Department of Transportation. to provide a rapid and cost-effective means for updating E-911 transportation networks using data from the most up-to-date, high-resolution, public and commercial satellites. To facilitate the integration of remote sensing technologies into transportation planning and management, the UNM consortium is also actively evaluating the existing remote sensing systems and research. The results will provide an on-line searchable database of information sources on remote sensing applications in transportation.

ASSOCIATED TECHNOLOGY APPLICATION PROJECTS BY SERVICE PROVIDERS

AERIS, Inc., in Great Falls, Virginia will demonstrate the capabilities of an advanced, airborne, ground-penetrating radar for detecting and mapping buried pipelines and early detection of leaks. The system will be flown over a simulated pipeline failure to address pipeline and spill detection capabilities as a function of distance/slant range and angle of incidence. The results will provide a functional capability for substantially increasing efficiency and reducing costs and schedule for projects involving pipeline detection and mapping, monitoring, and leak detection, as well as site investigation and assessment. Site testing is planned over several sites in Oklahoma.

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EarthWatch, Inc. in Longmont, Colorado, and its project partners Pacific Gas and Electric Company, Lawrence Livermore National Laboratory and Chevron Information Technology Company, will detect and characterize potential pipeline disruptions caused by natural hazards such as landslides and seismic activity on a selected section of natural gas pipeline in California. The project will employ interferometry and high-resolution imagery from satellite and airborne-based remote sensing systems to quantify surface elevation displacement. The expected project outcome will be a product that will enhance existing risk assessment methods.

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Helicopter with radar equipment



Example of above- and below-ground pipes used in system performance tests



Oil spill from leaking wellhead to be used in system tests

COMMERCIAL REMOTE SENSING TECHNOLOGIES
APPLICATION TO TRANSPORTATION

A PARTNERSHIP FOR ADVANCING TRANSPORTATION PRACTICE



Regional Traffic Monitoring

Focusing on congestion, mitigation and traffic flow



Environmental Impact Assessment

Mitigating environmental impact caused by transportation



Transportation Infrastructure Management

Managing critical transportation infrastructure



Hazards Safety and Disaster Assessment

Assessing risks and preparing for unplanned events



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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

